

University Concept Team Final Report

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The Team

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Tap academic creativity, balance
with ATM and flight ops expertise

The Charge

- Develop Future Concepts
- Identify Transition Paths
- **Identify Research Agenda**

Conduct 5 2-day meetings (Jan – June, 2002)
Deliver Final Report (late 2002)

Our Approach

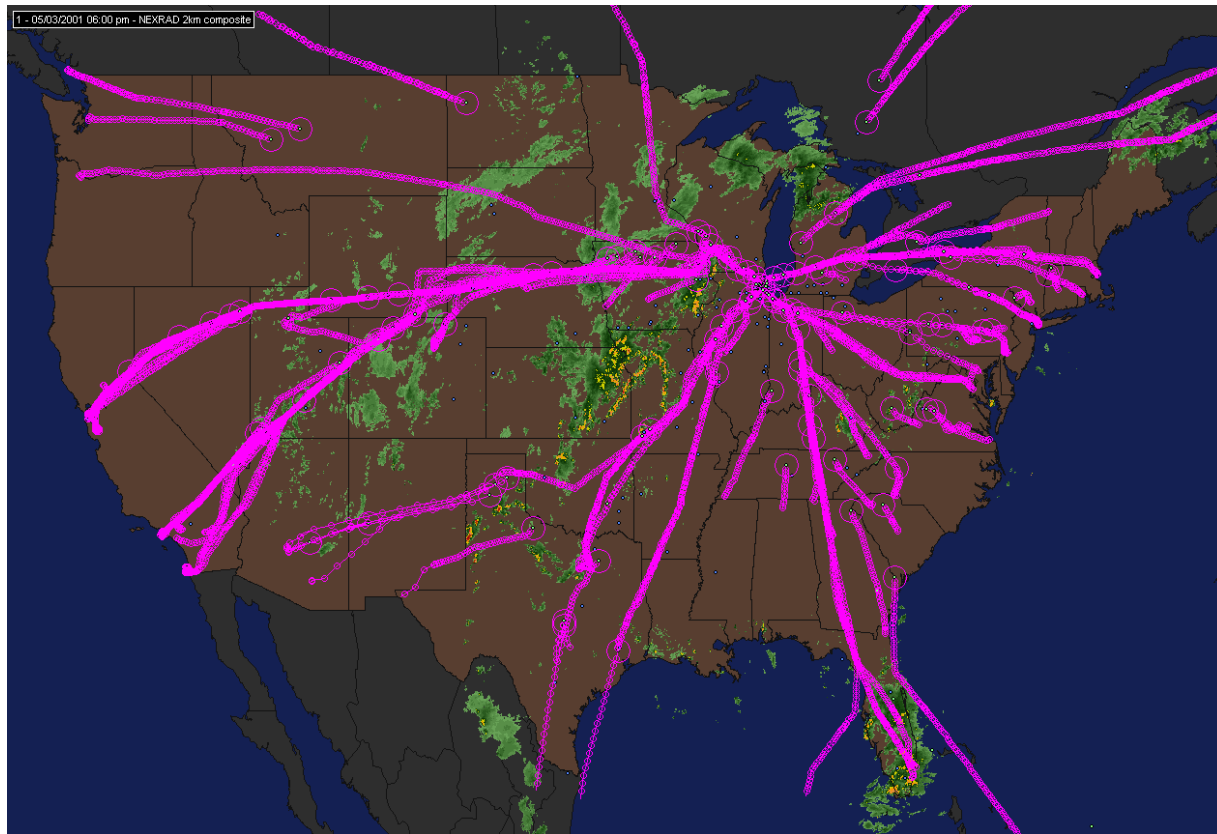
- Identify *drivers, inhibitors*, and *transition issues*
- Brainstorm *concepts* to accommodate these
- Identify *research questions* related to concepts
- Develop high level cut at possible *transitions*
- Identify *cross-cutting research questions*

Drivers

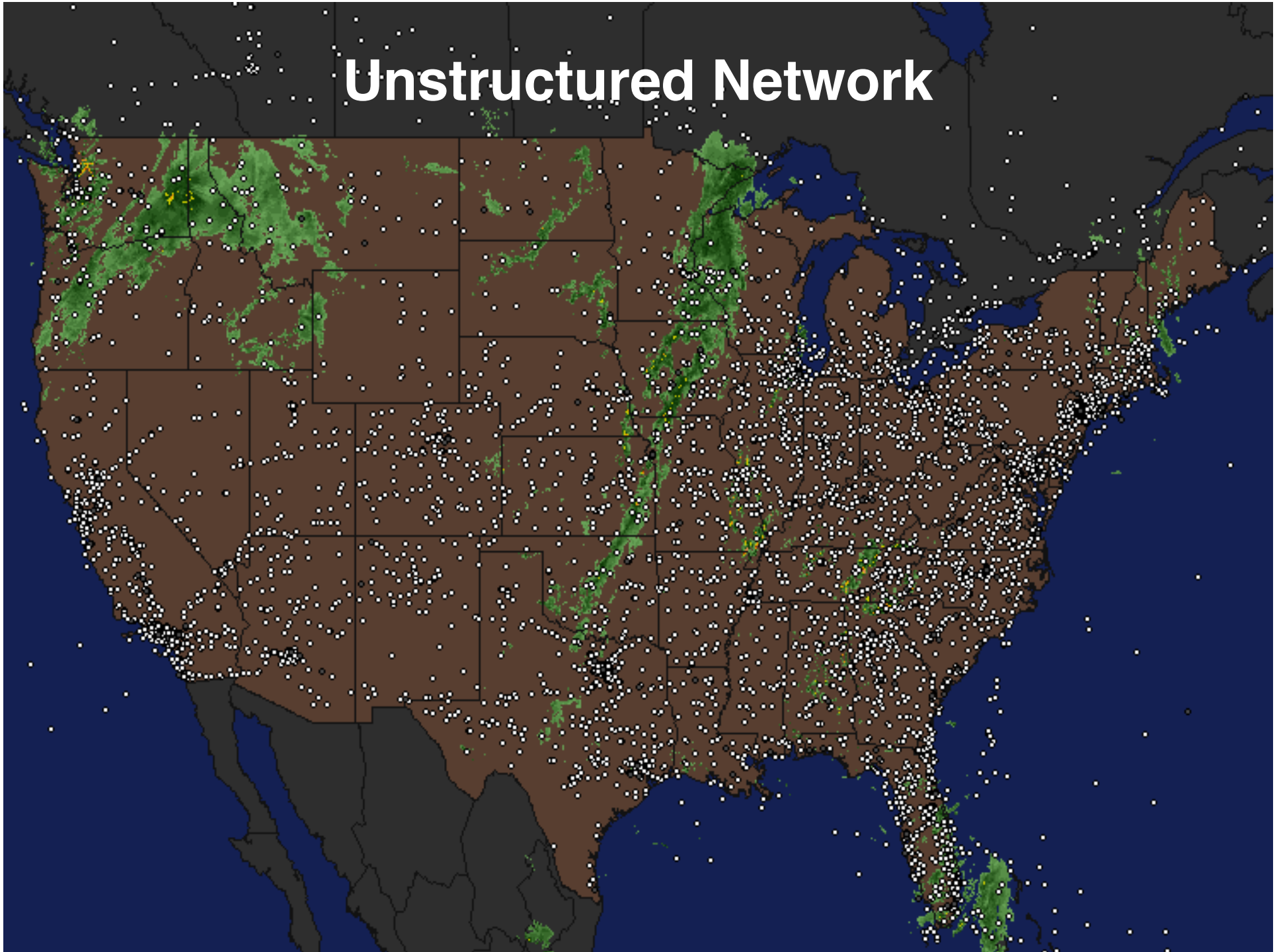
Two Very Different Demand Trends

- High-end:
 - Demand at highly utilized urban airports will continue to exceed capacity
- Low-end:
 - Fractionals; air taxi; RJs
 - Low-cost carriers using smaller airports near major urban areas
 - Cargo carriers using smaller aircraft
 - New GA aircraft

Structured Network Example



Unstructured Network



Other Drivers

Safety - a first principle

Security - inherent system requirements and operational needs

International Competition – Tension:
globalization vs. “what’s best for U.S.”

Future must be driven by policy for public benefit, not vested interests of special interest groups

Change Inhibitors

- **Affordability**
- **CNS Technology**
- **Environment**

Transition

Transition problems have been an inhibitor

- Our team thinks it's important to learn from the past and understand what is required for successful transition to a new concept
- Benefits driven transition not likely to work! Government may have to mandate equipage
- Need to address economics, implementation and operational policy, and stakeholder positions

Culture extremely stable – a transition inhibitor

Study Overview

- To deal with drivers, this study developed concepts and R&D for a range of airspace:
 - Concepts for “High density airport system” – making the best use of our national resource
 - Concepts to enable IMC operation to and from lower density airports
- Major airports will be a primary sources of bottlenecks in foreseeable future. We identified some approaches for attacking this problem.
- We identified high payoff research in case we are not successful in moving to new concepts and are forced to stay with current ATM paradigm.
- Note: Concepts are not comprehensive, not mutually exclusive

Concepts for High-End Network

- Tube Concept
- Highly Interactive Dynamic Planner

High Density Network: The Tube Concept

- Between High Volume Airports
- Highly Structured Routing for Efficiency
- Potentially limited operator flexibility, similar to TRACON flows but extend throughout network
- Maximum utilization of key resources (airports and airspace)
- Inner Loop Control goes to aircraft (RTA, In-Trail Separation, Pair-wise Maneuvering) to increase predictability and capacity
- Outer Loop control may go to the controller who can modify tube flows, control sequence, scheduling etc.

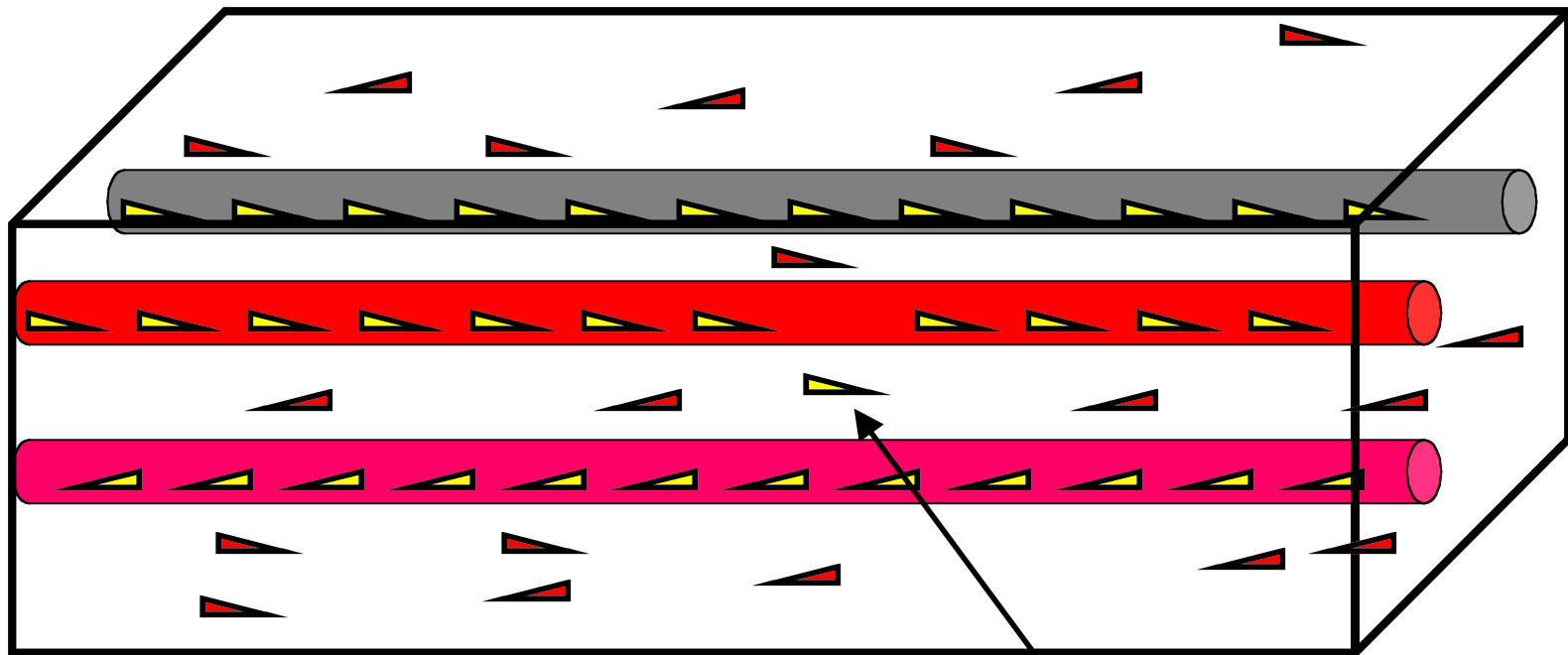
Power of tube is to create an abstraction that allows the controller to deal with many aircraft

The Tube Concept (cont'd)

- Highway metaphor (std routes, on-off ramps, breakdown lane, standard detours around obstructions such as weather)

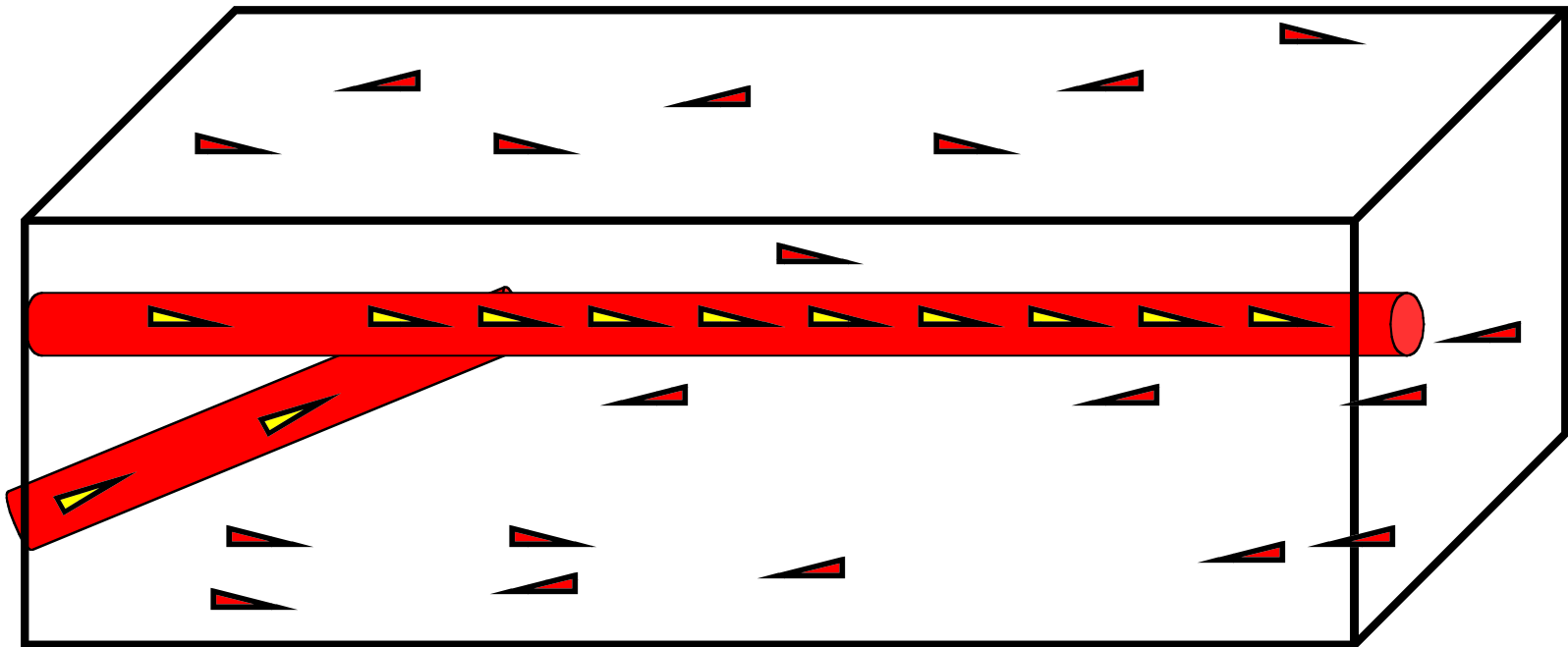
Tube Concept

Interleaved Structured and Unstructured Airspace



Problem Aircraft Exits Tube into
Unstructured Airspace
(Breakdown Lane) and Diverts
to Backup Airport

Tube Concept On-Ramp



The Tube Concept (cont'd)

- Ability to use scarce resource (high volume airport) justifies stringent equipment and operating constraints
- Requires a redesign of airspace and procedures
- Best chance for early capacity and predictability increase

Tube Concept - *Transition*

- **Demonstrate in Experimental Corridors** in High Value Target Markets (get participation of one or more operators)
 - ORD-NYC
 - LA-SFO
 - Washington-New York-Boston
 - LA - Las Vegas
- Limited corridors, simple on/off ramps, break-down lanes
- Pair wise self separation (station keeping) for closer spacing
- **Keep technology and procedures simple**
- Give preference to demo participants
- **# of corridors grows as we get experience**
- Control paradigm for tubes will change as sophistication of a dynamic tube system grows

Tube Concept - *Research*

- Role of Human in the system (Pilot, Controller, Dispatcher)
- Decision Support Tools (Flight Deck, Ground Based)
- Tube Control Methodology (Station keeping, RTA, 4D path?)
- Separation Assurance within tubes
- Tube Dynamics – Changes to tubes in response to weather, wind, turbulence or other perturbations
- How is planning and scheduling done?
- How do aircraft enter and exit tubes?

Tube Concept – *Research (cont'd)*

- Tube merges/splits/etc
- What are limits of tubes (i.e. does it get too complex? Can we deal with uncertainties? etc)?
- How do you deal with different capabilities of aircraft (esp. speed)?
- How do you handle failures?
- What are appropriate access, priority, and equipage policies to achieve desired impacts?
- How do you deal with aircraft flying outside the tubes?

High Density Network: Highly Interactive Dynamic Planner

- Goal - Concept will achieve the maximum capacity of high density airport/airspace system while satisfying user schedule and efficiency needs.
- Core Ideas
 - Dynamic air-ground negotiation of trajectories
 - Gate-to-gate scheduling based upon collaborative ground-based generation of a mix of RTAs and optimal 4 D conflict-free trajectories for all IFR aircraft throughout an entire day;
 - Cooperative sharing (between air and ground) of the responsibility for executing, revising, and rescheduling (as needed) the 4 D trajectory; and
 - Delegation of separation assurance to the flight deck

Highly Interactive Dynamic Planner

Transition

- Could evolve from tube concept
- Start in high altitude, high density en route airspace
- Gradually include more altitudes, lower density routes

Highly Interactive Dynamic Planner - *Research*

- **Roles** of Pilots, Controllers, Dispatchers in planning, execution, and replanning processes
- Nature of **planning and negotiation process** – how do you set up a national plan, how do you replan, how do airlines negotiate
- Dealing with major **anomalies** and achieving **stability** of the planning/replanning processes
- How to **avoid over constraining** the problems
- How **brittle** is concept to anomalies and failures?
- How **tightly do you control**? (buffers, spare space)
- What are potential **failures**? How do you deal with them?
- Can you **isolate problems** to keep anomalies from spreading?

Concepts for Low-End Network

- Autonomous IMC en route/terminal operations
- Autonomous IMC airport operations

Autonomous IMC En Route/Terminal Operations

By 2025, no longer “low density” – we predict too many planes for ATC as we know it today

- Separation responsibility goes to aircraft
- Traffic management limited to density control
- Sequencing and interaction done by procedure and rules of road
- Requires an increase in safety over today’s VFR system (GA VFR safety is an order of magnitude lower than commercial)
- All planes must be equipped
- Restricted zones that aircraft can’t fly into (avionics protection)
- Capable of dealing with weather problems – many of the aircraft can’t fly over weather!

Autonomous IMC En Route/Terminal Operations

- *Transition*

- Demo in Parallel to High Density Network
- Initial Demos in Low Density Regions
 - Oceanic
 - Alaska
 - High altitude
 - Low density, low altitude typical “trial” regions
- Expand to larger regions at lower altitudes (below 17,000ft?)
- Mandating equipment will accelerate transition

Autonomous IMC En Route/Terminal Operations - *Research*

- What are **procedures and technologies** necessary for Autonomous Operations?
- What are airspace “**dynamic density**” limits in airspace with less structure?
 - for safety?
 - for communications?
- What is **minimum equipage** necessary for different user categories?
- What are **failure and degraded modes** and how do you handle them? (avionics, ground monitor, ground equip, etc.)
- What kind of **ground “ATM” function** is needed?
 - density control
 - security monitoring
 - infrastructure monitoring
 - search and rescue
- How do you deal with **adverse weather**?
- What are **human roles**, including interaction with ATM?

Autonomous IMC Airport Operations

- **Goal:** increase the IMC capacity at non-towered airports without the need for adding traditional air traffic control
- Aircraft are responsible for self-separation and self-sequencing
 - Fully distributed? Automated ground support?
- Aircraft responsible for landing, taxiing, and takeoff
- (Automated?) Air Traffic Management is responsible for density control

Autonomous IMC Airport Operations *Transition*

- Introduce:
 - At typical airports with relatively low activity, on a regional basis
 - In communities that believe that airport growth will bring economic benefits
- (SATS demo program in Florida is a good example)

Autonomous IMC Airport Operations *Research*

- Feasibility?
- Hourly rate (10-15)?
- Distributed, airborne sequencing and spacing only?
- Density control?
- Separation criteria?
- CNS and avionics requirement?
- Ground based infrastructure?
- Unequipped aircraft?
- Interface to ATM system (does ATM deliver aircraft to a “metering fix”?)
- Pilot qualifications and training?

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Capacity Constrained Airports

- Demand Management
- Regional Airport System
- R&D for added capacity

Crosscutting Research

- **What are elements of a successful transition?**
 - Look at historical lessons learned
 - Understand major transition factors – incentive strategies; individual vs global benefits; culture; labor; role of policy in transition; equipage strategies
 - Major change will be accomplished incrementally
 - Impact of policy on concepts

- **- Understanding current and future ATM system behavior/dynamics**
 - Non-linearities – models
 - Use of performance and observational data
 - Disturbed behavior; brittleness; stability
 - Demand and its evolution
 - Failure modes; complexity; limiting factors for specific concepts
 - Handling anomalies – e.g., when many flight paths are to be changed? What are conditions required to keep system stable?

- **Human factors**

- Multi-state system operation – transition, awareness of state
 - Coordination
- Information requirement
- Failure modes and effects – role of human
- Quantification for parameterization of system loads
- Workforce skill mix of the future - selection and training
- Automation and human roles
- Span of control – time phased hierarchy

- **Separation standards –some examples:**

- Dynamic wake vortex separation standards
- Time based separation
- Relation to CNS; impact of intent
- Standards for different concepts/airspace
- Criteria for separation standards

- **Ways to reduce capacity variability**
 - What causes it
 - How do you control/manage it
 - What is the capacity variability that the system must be designed around – buffers etc (e.g., – security, wake vortex, weather , airport arrival rate)

- **4D Planners vs. Self-Separation**
 - Trades (advantages/disadvantages) between 4D conflict free trajectory planners and air-to-air self separation

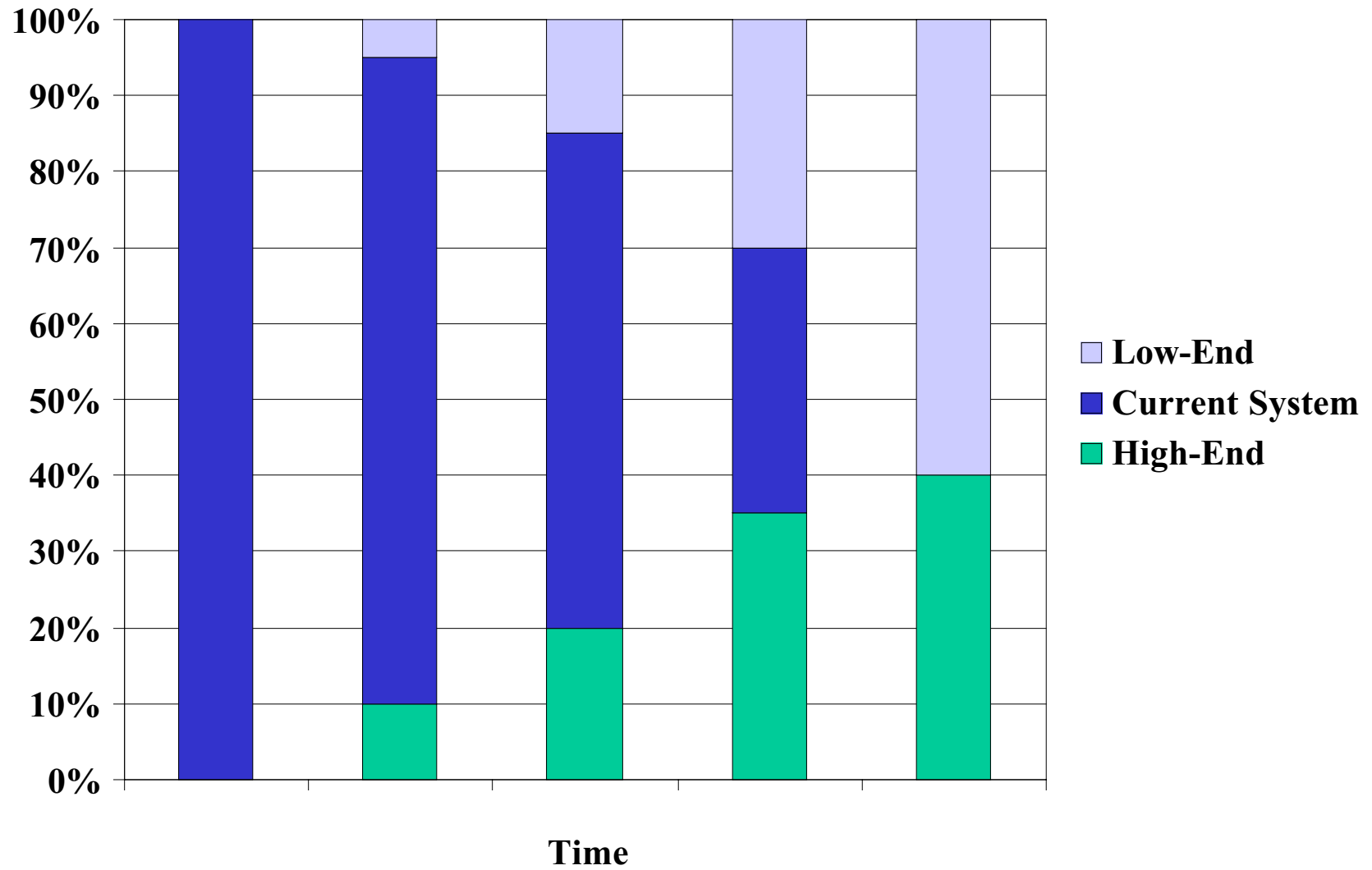
- **RTA approaches**
 - What are the limits on achievable performance in real world conditions
 - Trade off predictability and tight to plan
 - RTA accuracy impact on performance of the system
 - Control architecture

- **Airspace Design**
 - What are criteria to segment airspace that provide meaningful capacity gains? How much segmentation is feasible? What are airspace density limits for safety, communications, etc.?
 - How do we make Oceanic Airspace more like Domestic En Route Airspace? (special issues associated with international considerations, ICAO, FIRs, and mixed equipage)
- **Weather**
 - Predictability
 - Option based weather analysis
- **Safety**
 - Need a safety methodology for new concepts
 - What are the alternative target levels of safety
 - What should safety metrics target numbers be
 - How do you infer safety metrics for very rare events
- **Benefit/Cost Analysis**
 - Need new methods to include societal benefits
 - Methods to consider differential cost sharing

Closing Thoughts

Ease of transition makes this set of concepts particularly appealing

- While High- and Low-End systems are introduced, rest of airspace will operate as it does today
- Eventually, we envision:
 - High end network expands
 - Low end network expands
 - Current system shrinks and may go away



Thank You!

Continue Current ATM Paradigm

- If the paradigm shift that we endorse does not take place:
 - Economy will adapt!
 - But won't get economic benefits of aviation (lobster will be hard to get in Kansas City)
 - Non-part 121 will slowly be driven out of transportation business.
- We will have a system that can't get close to meeting demand
- More ATM by dispatchers is likely
- Demand management will become a necessity
- We identified high payoff research for existing paradigm